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Three Models for Macro-Simulation and Population Projection

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Abstract

In this paper three variations of a generalized simulation model for tracing the impact of mortality and fertility on age composition and total population size of a population closed to migration are developed. Computer programmes that can be used on an IBM PC to implement these models are available from the author.

Introduction

Simulation is one method of assessing the effect of the interaction of different components of a complex model. In demography, macro as well as micro simulations have been developed to evaluate the impact of various factors on population size, composition, labour force, etc. The starting point of almost all population models is an initial population of individuals and their characteristics. The models simulate events that happen in individual's lives and predict the characteristics of the population at a future date. The models may differ in the way they handle events, time, and individual members of the population. Models which take large groups of individuals at a time are "macro" models. "Micro" models simulate the life histories of each individual separately using a Monte Carlo process. The events occur to individuals in a random process. POPSIM, developed by Horvitz and others (1971), is a micro model designed to simulate the processes of marriage, fertility, and mortality in a population.

Macro-models consider the population as a number of groups of individuals having the same state at the beginning of the period and simulate how many of these will be in different possible states at the end of a period. Population projection is an example of the type of computations usually carried out with aggregated data for the purpose of simulation. Potter and Sakoda (1966), for example, developed a macro model of reproduction to study the effect of various factors on fertility.

In this paper three simulation models are discussed. Each traces the changes in the age-sex composition of a population and any characteristic (such as dependency ratio) that depends on the age structure. These models will be useful for students in the

social sciences who may lack the necessary mathematical skill to understand the theories of stable population, quasi-stable population, and weak ergodicity (Lopez, 1961; Coale, 1972). The three models are translated into computer programmes which will run on any computer system with a FORTRAN compiler. Most computer programmes published for demographic analysis (for example U. S. Bureau of Census, 1976) are designed to be used in a batch processing environment with cards as the input medium. The simulation programmes described in this paper are mainly intended for computer systems with a time sharing environment and terminals. These programmes can also be used on IBM personal computers or compatibles with a FORTRAN compiler. An interactive programme has several advantages over a batch-oriented one: the errors can be detected and corrected immediately; the selection of various options is dynamic and under the control of the user; the results of the simulation can be utilized for further modification of the parameters selected later.

Description of the Models

These models are primarily population projection models, rather than population forecast programmes. The input parameters required have been reduced to a minimum in the first model, to give users a wide latitude in selecting a country for analysis. Complexity and data requirements increase progressively for the second and third simulation models.

There are several methods of population projection to get the age-sex composition of a population at a future date. The cohort-component method is recommended by most demographers (Shryock and Siegel, 1973), and involves the separate projection of mortality, fertility, and migration. Here it is assumed that the population is closed to migration, or that migration is very insignificant. Mortality is incorporated in the programme as a series of survival ratios, by age and sex, from the model life tables (Coale and Demeny, 1966) for various levels of mortality. This allows the user to change the mortality level at any time by simply specifying the expectation of life at birth for females. The programme calculates the survival ratios for males and females by interpolation. In the second and third models, the user is required to provide the survival rates for the country. Fertility level is incorporated as age-specific birth rates and can be changed by giving the total fertility rate. The programmes use a typical age pattern of fertility to calculate the corresponding age-specific birth rates.

Three Simulation Models

Model	Input parameters	Variables that can be changed
SIMUL1	Expectation of life at birth Total fertility rate (TFR)	Expectation of life at birth TFR
SIMUL2	Survival rates for males and females TFR	TFR
SIMUL3	Survival rates for males and females Age specific birth rates	Survival rates TFR

Model 1 is useful for developing countries. The Model Life Tables (Coale and Demeny, 1966) are applied to estimate the survival rates for given expectation of life at birth. Model 2 is designed for countries with relatively high expectation of life and where the change in mortality is negligible. Model 3, which requires more detailed data, is applicable for countries in which both mortality and fertility are likely to vary.

Some Salient Features of the Programme SIMUL1.

This programme reads the base data from FORTRAN unit 8. This input file should have the following data: the first line should be the total number of countries in the file; the name of the country is given in the next line; the following line should give the base year; the subsequent six lines should contain the age distribution of males and females in five-year age groups, starting at 0 to 4 and ending in 80+. It is acceptable to put the last few age groups as zero if the available data have fewer age groups. The next two lines should give the life expectancy at birth for females and total fertility rate, respectively. This sequence of input data is continued for all of the countries that one wishes to be included. There is no special format for the input data, but the numbers should be separated by at least one space from one another. The first 11 lines of a typical data set assigned to unit 8 are given below.

```
65
Nepal
1981
```

```
1190581 1117141 919290 695746 636929 570192 468270
461873 376720 329439 290103 188064 191656 101189 83143
35096 39904
1123924 1073305 787731 632655 698769 591478 507131
431399 376068 289368 251919 157685 175839 87394 73643
31297 37900
45.10
6.1
```

The first line shows that there are 65 countries included in the file. The second line gives the name (Nepal) of the first country in the list. The base year for which the data is included is 1981. The expectation of life at birth for females is 45.1 and the total fertility is 6.1. Since there are 65 countries in the file, the total number of lines of data will be 651. A list of the 65 countries for which data is included is given in the Appendix.

A Sample Output from the Programme.

Some selected portions of the printed output obtained by running the programme are given below. Notice that we have selected Nepal for our simulation. For the first 15 years no change is made, then the expectation of life is increased, and finally after 30 years the total fertility is reduced to 5.0. When the user chooses to stop the process, a summary of changes in age distribution and vital rates is printed out. The following is an example of the printed output obtained by running the programme.

```
This is a Macro simulation model of a closed population to
study the effect of changes in  mortality and fertility on
the age composition, total number of births, deaths etc.
Select a country from the list by giving the number
corresponding to it. Enter the country code
1
```

Nepal
Base data for projection
Year 1981

AGE	Male	Female	Survival Rate Male	Survival Rate Female
0 - 4	1190581.	1123924.	0.7982600	0.8218900
5 - 9	1117141.	1073305.	0.9274100	0.9288000
10 - 14	919290.	787731.	0.9773200	0.9757600
15 - 19	695746.	632655.	0.9771000	0.9752400
.....				
70 - 74	83143.	73643.	0.6951000	0.7367000
75 - 79	35096.	31297.	0.5878700	0.6303600
80+	39904.	37900.	0.3600200	0.3856100
Total	7695336.	7327505.		

```
Age specific fertility rate for the age groups
15-19, 20-14, .... 45-49
0.11223 0.30289 0.30772 0.23652 0.16532 0.08326 0.01207
Year 1981
The total fertility rate is      6.100
The expectation of life at birth
      Males   42.116
    Females   45.100
Now you may further project the population
Type   0    to quit
       1    to change total fertility
       2    to change the expectation of life at
            birth
       3    to keep the same eo and TFR and proceed
3

Write the number of five year cycles though
which the population should be projected
(with the same level of mortality and fertility)
If you write 3 the population will be projected
through 15 years
3
                          Nepal
                       YEAR 1986
AGE                TOTAL      MALES      FEMALES
  0 -   4       2877029.   1452351.   1424678.
  5 -   9       2148057.   1104157.   1043901.
  ......           .....      ....       ...
 70 -  74        134720.     70336.     64383.
 75 -  79         95299.     48877.     46422.
 80 +             53685.     27001.     26683.
TOTAL          16894688.  8602780.   8291908.

Year 1996
The total fertility rate is      6.100
The expectation of life at birth
      Males   42.116
    Females   45.100
Now you may further project the population
Type   0   to quit
       1   to change total fertility
       2   to change the expectation of life at birth
       3   to keep the same eo and TFR and proceed
2
What is the new expectation of life at birth
for females? (Between 27.5 and 77.5)
47
```

Summary

Year	TFR	CBR	CDR	% in age group		
				<15	15-64	65+
1981-1986	6.100	44.525	21.066	42.40	54.19	3.40
1986-1991	6.100	42.913	20.700	41.71	55.22	3.06
1991-1996	6.100	42.942	20.517	42.46	54.37	3.16
1996-2001	6.100	43.272	19.073	42.29	54.56	3.13
2001-2006	6.100	43.646	19.054	42.65	54.18	3.16
2006-2011	6.100	44.094	19.105	43.10	53.75	3.14
2011-2016	5.000	36.837	17.937	41.50	55.36	3.13
2016-2021	5.000	37.913	17.977	40.04	56.80	3.14
2021-2026	5.000	38.960	18.239	38.64	58.20	3.15

Outputs from SIMUL2 and SIMUL3 are similar to the one given above. The main difference is in the options presented to the user. Copies of these three programmes may obtained from the author at the Population Research Laboratory.

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U. S. Bureau of Census (1976) "Computer Programmes for Demographic Analysis". Washington, D.C.

APPENDIX

List of countries which may be selected from the programme SIMUL1

1 Denmark
2 Ireland
3 United Kingdom
4 Austria
5 Belgium
6 Germany (West)
7 Bulgaria
8 Germany (East)
9 Hungary
10 Romania
11 Greece
12 Italy
13 Portugal
14 Spain
15 Yugoslavia
16 Poland
17 Czechoslovakia
18 Uruguay
19 Brazil
20 Chile
21 Argentina
22 Bolivia
23 Equador
24 Paraguay
25 Peru
26 Guatemala
27 Mexico
28 Cuba
29 Barbados
30 Nicaragua
31 Panama
32 Trinidad & Tobago
33 Venezuela
34 Haiti
35 Israel
36 Iran
37 Kuwait
38 Syrian Arab Republic
39 Turkey
40 Burma
41 Nepal
42 Malaysia
43 Philippines
44 Singapore
45 Thailand
46 Korea
47 China
48 Indonesia
49 Bangladesh
50 Pakistan
51 Sri Lanka
52 Cyprus
53 Malawi
54 Egypt
55 Mauritius (island)
56 Tanzania
57 Kenya
58 Senegal
59 Mali
60 Cameroon
61 Zambia
62 Guinea(Bissau)
63 South Africa
64 Zimbabwe
65 Ethiopia

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